

NON-PROVISIONAL APPLICATION FOR UNITED STATES PATENT

FOR

Low Current Consumption Detector Circuit & Applications

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FIELD OF THE INVENTION

[0001] The present invention relates generally to the field of circuits.

BACKGROUND OF THE INVENTION

[0002] It is common for integrated circuits to have power-on circuits that detect for the application of voltage or current. Typically, a detector circuit remains active when the host system hosting the integrated circuit with the detector circuit is in a stand-by mode (e.g. a power saving mode). For various applications, e.g. wireless applications, low power consumption is an important attribute.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references denote similar elements, and in which:

[0004] **Figure 1** illustrates a block diagram view of a power-on circuit, in accordance with an embodiment of the present invention;

[0005] **Figure 2** illustrates the detector circuit of **Figure 1** in further detail, in accordance with one embodiment;

[0006] **Figure 3** illustrates the switching circuit of **Figure 1** in further detail, in accordance with another embodiment of the present invention; and

[0007] **Figure 4** illustrates an example host system having an example integrated circuit incorporated with the power-on circuit of **Figure 1**, in accordance with one embodiment.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0008] Illustrative embodiments of the present invention include, but are not limited to, a detector circuit, a switching circuit, a power-on circuit formed with the detector and switching circuits, and integrated circuits/systems formed with the power-on circuit.

[0009] Various aspects of the illustrative embodiments will be described using terms commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some of the described aspects. For purposes of explanation, specific numbers, materials, and configurations are set forth in order to provide a thorough understanding of the illustrative embodiments. However, it will be apparent to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the illustrative embodiments.

[0010] The phrase "in one embodiment" is used repeatedly. The phrase generally does not refer to the same embodiment; however, it may. The terms "comprising", "having" and "including" are synonymous, unless the context dictates otherwise.

[0011] Referring now to **Figure 1**, wherein a block diagram view of a power-on circuit, in accordance with one embodiment, is shown. As illustrated, power-on circuit **100** includes detector circuit **102** and switching circuit **104** coupled to each other and to supply terminal **106**, ground terminal **108**, and output terminal **112** as shown.

[0012] Detector circuit **102** is employed to detect application of voltage at SUPPLY terminal **106** (also referred to as input terminal). More specifically, detector circuit **102** detects for voltage in excess of a supply voltage threshold. Detector circuit **102** uses DETECT signal **110** to communicate its detection results to switching circuit **104**.

[0013] Switching circuit **104** is employed to pull OUTPUT terminal **112** to ground, if voltage applied to SUPPLY terminal **106** is not in excess of the supply voltage threshold. Further, switching circuit **104** is employed to couple the voltage applied to SUPPLY terminal **106** if the voltage applied is in excess of the supply voltage threshold. Switching circuit **104** performs its operation based at least in part on the state of DETECT signal **110**.

[0014] Accordingly, detector circuit **102** and switching circuit **104** are complementarily designed. More specifically, in various embodiments, detector circuit **102** may be designed to output the supply voltage at SUPPLY terminal **106** as DETECT signal **110** when the supply voltage is below the supply voltage threshold, and ground the output terminal/node for DETECT signal **110** when the supply voltage exceeds the supply voltage threshold.

[0015] Further, at least detector circuit **102** is designed to be a low current consumption circuit, thereby improving the power performance of a host system hosting an integrated circuit incorporated with detector circuit **102**.

[0016] In various embodiments, each of detector circuit **102** and switching circuit **104** may be formed with one or more transistor devices, e.g. MOSFET. In various embodiments, detector circuit **102** effectuates the low current consumption attribute by including at least one transistor device, e.g. a depletion NMOS device with its gate coupled to its source. The depletion NMOS device consumes substantially the same low amount of current, whether the supply voltage is below or above the supply voltage threshold. [MOSFET = Metal Oxide Semiconductor Field Effect Transistor, and NMOS = n-type Source and Drain, p-type Body connected to Ground.]

[0017] Figure 2 illustrates detector circuit **102** in further detail, in accordance with one embodiment. As illustrated, for the embodiment, detector circuit **102** may include transistor devices **202** and **204** coupled to each other, SUPPLY terminal **106**, GROUND terminal **108**, and node for outputting DETECT signal **110** as shown.

[0018] In various embodiments, transistor devices **202** and **204** may be designed to have complementary different trigger voltages. More specifically, transistor device **202** may be designed to have a lower trigger voltage, whereas transistor device **204** may be designed to have a higher trigger voltage. The detector trip point, which is the supply voltage level that causes DETECT signal **110** to denote application of supply voltage at SUPPLY terminal **110** is a function of these trigger voltages. Accordingly, the detector trip point may be varied for different designs by varying the trigger voltages, which may be varied e.g. by varying the aspect ratios (width/length) of the transistor devices.

[0019] In various embodiments, transistor devices **202** and **204** are MOSFETs. More specifically, transistor device **202** is a depletion NMOS device having a negative threshold voltage (hereinafter, also referred to as M1), whereas transistor device **204** is an enhancement NMOS device having a positive threshold voltage (hereinafter, also referred to as M2). Thus, the earlier described trip voltage is the difference between these threshold voltages. For example, if the threshold voltage of M1 is -0.1v , and the threshold voltage of M2 is 0.7v , the detector trip point is 0.8v . [Hereinafter, an enhancement NMOS device may also be referred to as a standard NMOS device or simply, a NMOS device.]

[0020] For the illustrated embodiment, M1 **202** is further configured to have its gate connected to its source.

[0021] Thus, during operation, when the supply voltage applied to SUPPLY terminal **106** is below the supply voltage threshold, M1 **202** is "ON", but M2 **204** is "OFF", allowing M1 **202** to pull the node outputting DETECT signal **110** to the supply voltage at SUPPLY terminal **110**. However, when the supply voltage applied to SUPPLY terminal **106** exceeds the supply voltage threshold, M2 **204** is "ON", pulling the node outputting DETECT signal **110** to ground. However, by virtue of the small gate drive across M1 (employment of low aspect ratio to provide low trigger voltage), the amount of current consumed by M1 is substantially the same below or above the supply voltage threshold.

[0022] As those skilled in the art will appreciate, in the prior art, a diode-connected load approach is often employed, which allows the current consumption by M1 to continue to rise with the increase in voltage applied. Thus, in contrast, embodiments of the present invention are more efficient in current consumption, that is, lower current consumption.

[0023] In the foregoing embodiment, the trip point of detector circuit **102** is the difference between the trigger voltages of M1 **202** and M2 **204**. In alternate embodiments, additional circuit elements may be employed to effectuate a trip point based on other relationships of the trigger voltages of M1 **202** and M2 **204** (beside merely their difference). For example, 4 resistors may be provided to the path between SUPPLY and GROUND, and the voltage between the "bottom" and the "second to bottom" resistor is coupled to the gate of M2 **204** instead. Assuming the trigger voltages of M1 **202** and M2 **204** are still 0.7v and -0.1v respectively, the trip point of

detector circuit **102** (with the above described modifications) now become $4 \times (0.7v - 0.1v)$ or 3.2v (instead of 0.8v as earlier described). With these adjustments, detector circuit **102** may be employed to detect application of higher voltages.

[0024] **FIGURE 3** illustrates switching circuit **104** in further detail, in accordance with one embodiment. As illustrated, switching circuit **104** includes a number of transistor devices **302** and **304** coupled to each other, SUPPLY terminal **106**, the node outputting DETECT signal **110**, GROUND terminal **108**, and OUTPUT terminal **112**, as shown.

[0025] In various embodiments, transistor devices **302** and **304** may be MOSFETs. More specifically, transistor device **302** may be a PMOS device (hereinafter, also referred to as M3), whereas transistor device **304** is a NMOS device (hereinafter, also referred to as M4). [PMOS = p-type Source and Drain, n-type Body connected to power supply.

[0026] Thus, during operation, when DETECT signal **110** is at the supply voltage (when the supply voltage applied to SUPPLY terminal **106** is below the supply voltage threshold (for the detector circuit of **Fig. 2**)), M3 **302** is "OFF", but M4 **304** is "ON", pulling OUTPUT terminal **112** to ground. However, when the node outputting DETECT signal **110** is grounded (when the supply voltage applied to SUPPLY terminal **106** exceeds the supply voltage threshold (for the detector circuit of **Figure 2**)), M3 **302** is "ON" and M4 **304** is "OFF", pulling OUTPUT terminal **112** to the supply voltage.

[0027] In the foregoing embodiment, switching circuit **104** includes two transistor devices. In alternate embodiments, switching circuit **104** may employ more or less circuit elements, including a single circuit element. For example, in lieu of the above described device arrangement, a single NOR gate may be provided as switching circuit **104** (with its inputs coupled to SUPPLY and DETECT). For such an embodiment, the NOR gate would output SUPPLY, when DETECT is "0". Accordingly, the term "switching circuit" as used herein in the specification and in the claim includes "circuits" having as little as a single circuit element.

[0028] **Figure 4** illustrates an example host system to host an integrated circuit incorporated with power-on circuit **100**, in accordance with one embodiment. As

illustrated, example system **400** includes microprocessor **402** incorporated with power-on circuit **100**. Further, system **400** includes memory **404**, and a number of I/O devices **406**, coupled to each other and microprocessor **402** via bus **408**.

[0029] Except for the incorporation of power-on circuit **100** with microprocessor **402**, elements **402-408** represent a broad range of these elements known in the art or to be designed. In particular, examples of I/O devices **406** include but are not limited to keyboard, pointing devices, display, mass storage, communication interfaces (both wire line based or wireless), and so forth.

[0030] In various embodiments, example system **400** may be a server, a desktop computer, a laptop computer, a tablet computer, a hand held computing device, and so forth. In other embodiments, example system **400** may be a set-top box, a CD player, a DVD player, a digital camera, a digital camcorder, a wireless mobile phone, and so forth.

[0031] Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a wide variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described, without departing from the scope of the present invention. This application is intended to cover any adaptations or variations of the embodiments discussed herein. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.